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Performance Evaluation of WiMAX 802.16e OFDM PHY LAYER

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***Abstract*— WIMAX is the new era of communication currently employed in some parts of the world. It is the latest technology approved by IEEE 802.16 group, which is a standard for point-to-multipoint wireless networking. WIMAX vision is to deliver "last mile" broadband connectivity to home or business locations, also its data rates are comparable with Cable and Digital Subscriber line (DSL) rates. It has the capability which connects to the ISP (Internet Service Provider) even when you are roaming outside home or office. The WIMAX technology can provide a cost-effective broadband access solution in areas beyond the reach of DSL and cable. The WiMAX technology is becoming the way to avert the impending crisis of rural connectivity i.e. it will be accessible till the last mile. This paper explains about the purpose of WiMAX, the study of WiMAX systems, its implications, its wireless capabilities and evaluates performance of WIMAX system under different combinations of digital modulation and different communication channels.**

***Keywords*— Ad-hoc, AODV, Black hole, MANET, WSN**

I. INTRODUCTION

WiMAX is a new broadband wireless access technology by IEEE 802.16e working group to serve the "anywhere anytime" access demands to the internet and ensure quality of service. WiMAX forum offers high data rate over large areas to a large number of users where broadband is unavailable. Broadband Wireless Access (BWA) has emerged as the promising solution for last mile access technology to provide high speed internet access in residential as well as the small and medium sized of that enterprise sectors. It is designed to accommodate both fixed and mobile broadband application. It can be used for many applications, including "last mile" broadband connections, cellular backhaul, and high-speed enterprise connectivity for business, due to its high spectrum efficiency and robustness in multipath propagation. The first version of the IEEE 802.16 standard operates in that the 10–66GHz frequency band and requires line of sight (LOS) towers. Later, the standard extended its operation through different PHY specification to 211 GHz frequency band enabling non line of sight (NLOS) connections, which require techniques that efficiently mitigate the impairment of fading and multipath.

WiMAX standards were developed by IEEE 802.16 group. These standards are based on wireless metropolitan area networking (WMAN) standards. WiMAX, is based on an RF technology called Orthogonal Frequency Division Multiplexing (OFDM), which is a very effective means of transferring data when carriers of width of 5MHz or greater can be used.

II. WIMAX SYSTEM MODEL

In WIMAX for end to end transmission to cover certain distance, the data is transmitted with the air interface model which vary according to the user demand application. In such cases WIMAX Physical layer has three Air interface model, single carrier modulated air interface, 256 point FFT OFDM Multiplexing, 2048 point FFT OFDMA scheme.

The primary goal is to build an IEEE 802.16-2004 OFDM physical layer to reduced BER using different modulation scheme. The coding technique is to select such code words that minimize or reduce the BER. This technique doesn't degrade the in-band and out-band spectrum but it suffers from bandwidth efficiency as the code rate is reduced.

With increase in data rate requirements, large bandwidths are needed to support it. Higher bandwidths (subcarriers) drastically increase the BER. In this system model the major blocks are channel encoder and decoder, modulation mapper and OFDM block. As per our simulation we depend on the 256 point FFT size to generate the data for baseband transmission , the entire data is transmitted using the OFDM transmission technique, which converts the data into an OFDM symbol by performing the corresponding operations, which includes a frequency-time transformation and the additional of a guard period.

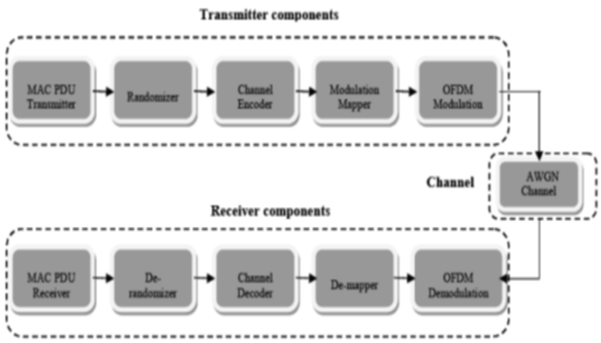

Fig.1 WiMAX System Model

III. WIMAX PHYSICAL LAYER

The WiMAX PHY layer is based on OFDM which is used to enable high-speed data, video, and multimedia communications and is used by a variety of commercial broadband systems including DSL, Wi-Fi, Digital Video Broadcast-Handheld (DVB-H) and MediaFLO, besides WiMAX. Physical layer set up the connection between the communicating devices and is responsible for transmitting the bit sequence. WIMAX 802.16 PHY-layer considers two types of transmission techniques OFDM and OFDMA.

Both of these techniques have frequency band below 11 GHz and use TDD and FDD as its duplexing technology. OFDM is a scheme that offers good resistance to multipath and allows WiMAX to operate in NLOS (non-line-of-sight) conditions. OFDM is widely addressed as the way to mitigate multipath for broadband wireless. OFDM is based on a transmission scheme called multi-carrier modulation, which divides a high bit stream into a number of low bit streams, which are each modulated by separate carriers called subcarriers or tones. The WiMAX RF signals use OFDM techniques and its signal bandwidth can range from 1.25 to 20 MHz. To maintain orthogonality between the individual carriers the symbol period must be reciprocal of the carrier spacing.

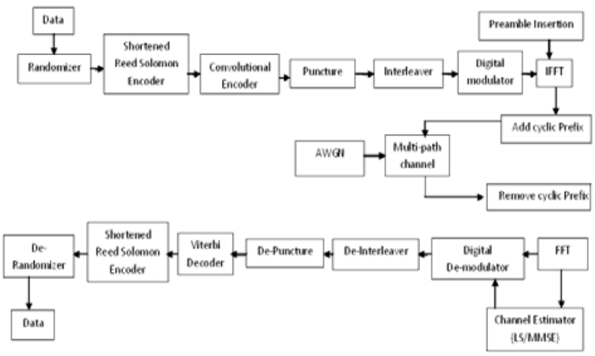

Fig.2 WiMAX Physical Layer

The various blocks of WiMAX Physical Layer are:

- Randomization:

Once the data packet is received from the higher layers, randomization is the first step to perform in the physical layer. Randomizer operates on a bit by bit fashion and each burst in downlink and uplink is randomized. The whole implementation of this phase is done with a Pseudo Random Binary Sequence (PRBS) generator.

- FEC- Forward Error Correction:

FEC is a technique used for controlling errors in data transmission over noisy communication channels. It is done on both the uplink and the downlink bursts and consists of concatenation of reed-Solomon outer code and a rate compatible convolution inner code.

  - Reed Solomon Outer Code:

Reed-Solomon error correction is a coding scheme which works by adding redundancy to the data to deal with the block errors that occur during transmission of the signal. The encoding process for RS encoder is based on Galois Field Computations to do the calculation of the redundant bits. Galois Field is widely used to represent data in error control coding is denoted by GF (2^m).

  - Convolution Coding

A convolution code is a kind of FEC code denoted by cc (m,n,k), where each m-bit information symbol to be encoded is transformed into n-bit symbol, where m/n is the code rate (n>m) and the transformation is a function of the last k information symbols, where k is constraint length of code. It mostly handles the random errors in data transmission.

  - Interleaving

Unlike Randomizer, Interleaving does not alter the state of the bits but works only with the position of bits. It aims at distributing transmitted bits in time or frequency domain or both to achieve desirable bit error distribution. The incoming data is randomized in two permutations where first permutation ensures that adjacent bits are mapped onto non-adjacent subcarriers while the second permutation maps the adjacent coded bits onto less or more significant bits of constellation thus avoiding long runs of less reliable bits.

The first permutation is defined by the formula:

mk = (Ncbps/12) * mod(k,12) + floor(k/12).

The second permutation is defined by the formula:

S = ceil (Ncpc/2)

Jk = s × floor (mk/s) + (mk + Ncbps – floor(12×mk/Ncbps)) mod(s)

Where:

K = Index of coded bit before first permutation

mk = Index of coded bit after first permutation

jk = Index of coded bit after second permutation

Ncpc = Number of coded bits per carrier

Ncbps = Number of coded bits per symbol.

Index of bits represented by jk is used during the modulation process.

- Cyclic Prefix Insertion

A cyclic prefix is added to the time domain samples to combat the effect of multipath. Four different duration of cyclic prefix are available in the standard. Being G the ratio of

CP time to OFDM symbol time, this ratio can be equal to 1/32, 1/6, 1/8 and 1/4

.AWGN (Additive white Gaussian noise) Channel

AWGN channel block adds white Gaussian noise to real or complex input signal. It adds real Gaussian noise when the input signal is real and produces a real output signal. Additive white Gaussian noise is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude.

The AWGN channel capacity is expressed as following equation

Cawgn = W log2 (1+P'/NoW) bits/Hz

Where the average received power is P'[w] and the noise power spectral density is No [W/Hz]

And P'/NoW is received signal-to-noise ratio (SNR)

- Rayleigh Fading Channel

It is a statistical model for propagation environment on the radio signal used by wireless networks. It assumes that the power of a signal passing through a transmission medium will vary randomly which is modelled as Rayleigh distribution. It is a reasonable model for troposphere and ionosphere signal propagation. This channel is most applicable when there is no line-of-sight between the transmitter and receiver.

IV. IEEE 802.16 PHY INTERFACE VARIANTS

The standard has assigned a unique name to each physical interface.

- Wireless MAN-SC™:

It is regarded as the only PHY specification that operates in 1066 GHz frequency band. It provides single carrier modulation with adaptive burst profiling, where transmission parameters in addition to all the modulation and coding schemes are tuned distinctively to each subscriber station (SS) in a frame fashion. The standard goes with Frequency Division Duplexing (FDD) and Time division Duplexing (TDD) along with comparatively less expensive half duplex FDD SS. This duplexing technique is common to all the PHY specifications. Access in uplink direction is done by aggregation of time division multiple access (TDMA) and Demand Assignment Multiple Access (DAMA) whereas the communication on the downlink in PTM Architecture is employed using Time Division Multiplexing (TDM).

- Wireless MAN-SCa™

Like Wireless MAN-SC™, it is also based on single carrier modulation targeted for 211 GHz frequency range. The only slight difference is that access is done by TDMA technique both in uplink and downlink, additionally TDM also supported in downlink.

- Wireless MAN-OFDM™

This PHY specification is based on orthogonal frequency division multiplexing (OFDM) with a 256 point transform to support multiple SS in 211 GHz frequency band where access is done by TDMA. This is the most suitable one to provide fixed support in NLOS environment because of OFDM and other features like multiple forward error correction method.

- Wireless MAN-OFDMA™

This PHY specification uses OFDM access (OFDMA) with at least a single support of specified multipoint transform (2048, 1024, 512 or 128) to provide combined fixed and Mobile BWA. Operation is limited to below 11 GHz licensed band. In this specification multiple access is provided by addressing a subset of the multiple carriers to individual receivers.

- Wireless HUMAN™

This specification is targeted for license exempt band below 11 GHz. Any of the air interfaces specified for 211 GHz can be used for this. This supports only TDD for duplexing

V. EXPERIMENTAL RESULTS

In this section, the simulation results obtained have been discussed. The system model implementation has been done in MATLAB on BER calculations for various digital modulation schemes like BPSK, QPSK, 64-QAM, 16-QAM. The result of the plot of the bit error rate versus signal to noise ratio which provide information about the systems performance. Model for the system has been developed for various modulation schemes and different coding rates like BPSK ½ , QPSK ½ , 16QAM ½,16QAM ¾, 64QAM ½, 64QAM ¾.

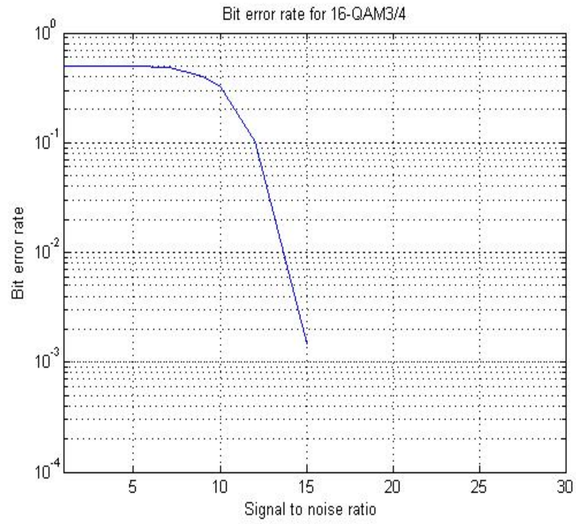

Fig.3 BER results versus SNR using BER 64 -QAM ¾ (cyclic prefix 1/32)

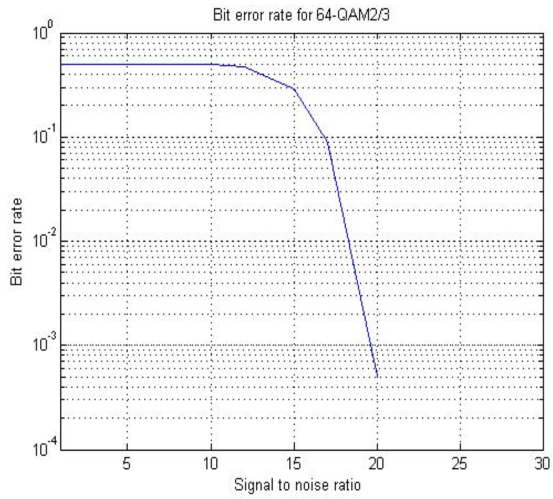

Fig.4 BER results versus SNR using BER 64 -QAM 2/3 (cyclic prefix 1/32)

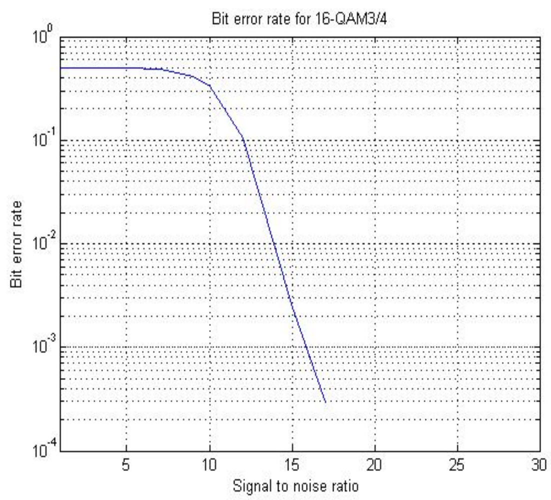

Fig.5 BER results versus SNR using BER 16 -QAM 3/4 (cyclic prefix 1/16)

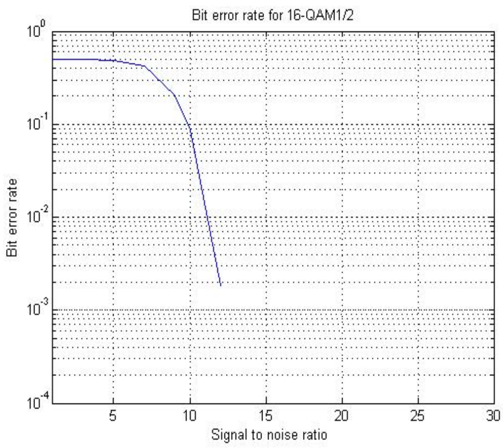

Fig.6 BER results versus SNR using BER 16 -QAM 1/2 (cyclic prefix 1/32)

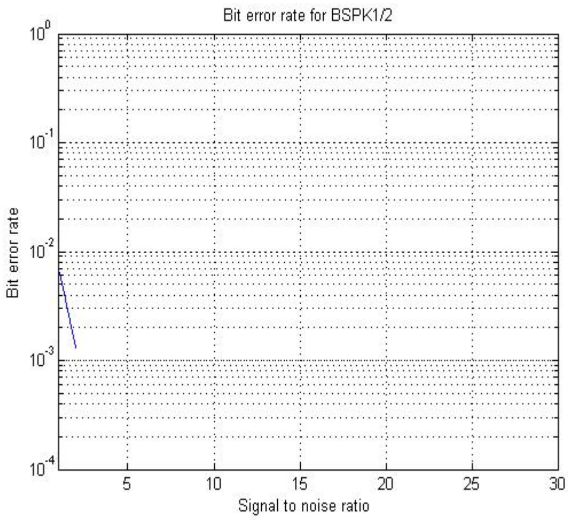

Fig.7 Bit Error Rate for BPSK1/2 (cyclic prefix 1/32)

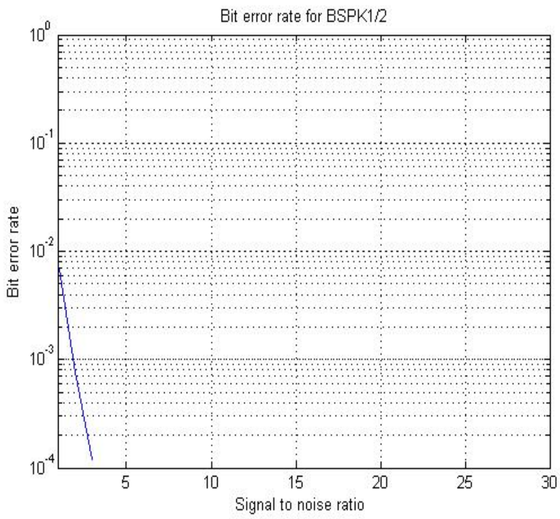

Fig.8 Bit Error Rate for BPSK1/2 (cyclic prefix 1/4)

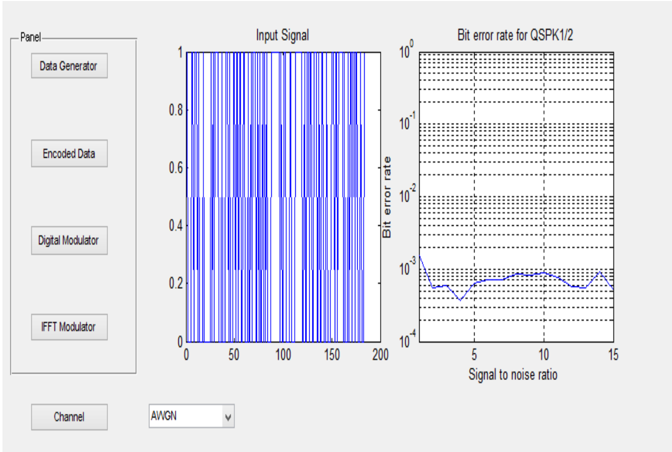

Fig.9 BER for QPSK ½ for AWGN

VI. CONCLUSIONS

The key contribution of this paper was the implementation of the IEEE 802.16 OFDM PHY layer using MATLAB in order to evaluate the PHY layer performance under reference channel model. The implemented PHY layer supports all the modulation and coding schemes as well as CP lengths defined in the specification. The overall system performance was evaluated under different channel conditions. A key performance measure of a wireless communication system is the BER. The BER curves were used to compare the performance of different modulation and coding scheme used. The effects of the CP, FEC and interleaving were also evaluated in the form of BER. These provided us with a comprehensive evaluation of the performance of the OFDM physical layer for different states of the wireless channel.

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